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CURRENT PROBLEMS OF MORPHOLOGY OF MOON'S SURFACE

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SUMMARY

Owing to the successful realization of the photographing of the Eastern sector of the Moon's far side with the aid of the automatic interplanetary station (AIS "ZOND-3") on 20 July 1965, the possibility has resulted of global survey of 95 percent of the entire lunar surface.

In connection with this, preliminary analysis of photographs from AIS Zond-3 is now performed: it includes the questions of morphological asymmetry of the lunar sphere, the characteristics of formations of new type ascertained on the far side of the Moon and the place of the Moon amongst other bodies of the solar system.

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1. With the delivery by the automatic interplanetary station (AIS) Zond-3 of the complex of photographs from the eastern sector of the far side of the Moon encompassing up to 35% of the surface of the invisible hemisphere, the main stage of the global survey of the Earth's satellite has been practically completed. Only two insignificant territories still remain uninvestigated: the region near the North pole and a narrow zone, adjacent to the South pole along the boundary of 1959 photographing. The aggregate area of "white spots" does not exceed 5% of the entire Moon's surface.

The accumulated information on the macrostructure of the superficial layer of the lunar sphere allows us to enter upon the solution of the complex of selenographic and planetological problems. Although the final solution of such a type of problems is impossible without subsequent space experiments, the already completed photographic survey of the far side allows us to discuss the preliminary results of the study of the nature of the lunar mantle.

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* TEKUSHCHIYE PROBLEMY MORFOLOGII POVERKHNOSTI LUNY.

These refer to the distribution of the coarsest formations, which is linked with the asymmetry effect of the lunar sphere, with the characteristics of the new-type formations made apparent on the far side of the Moon, with the classification of morphological shadings of details over the entire lunar surface, and finally, with the place of the Moon among the other bodies of the solar system. The possibility of considering these problems now arises for the first time, and obviously, such a consideration must precede the further detailed statistical, topographic and astrophysical investigations of various regions of the lunar sphere.

2. The morphological study of the structure of lunar crust, connected with the distribution of continental and mare regions, is now recognized as the most important selenographic problem.

The regions of maria on the visible side of the Moon, of which the main characteristic is the low albedo, occupy nearly one half of the surface. The mare formations may be subdivided by their shape into those accurately oval, of Mare Imbrium, Mare Serenitatis, Mare Crisium and Grimaldi type, and the irregular similarly to Oceanus Procellarum, Mare Frigoris, Mare Nubium and the mosaic ones, such as Mare Australe, the region of maria Spumans, Undarum, Anguis, and the neighboring dark craters, and also the region near the Joliot Curie crater, called by Franz Mare Novium (see Catalogue MAC No.140a [1, 2]).

The continental surface of the visible side, saturated by hills and mountain ranges, has a higher albedo than the mare regions. If for the latter solitarily disposed craters are characteristic, the continents are characterized by multiple superimposition of craters. As a rule, craters of small diameter are superimposed on craters of larger size.

The difference from the standpoint of brightness between the mare and continental regions is particularly clearly apparent in fullmoon periods, when the shadows of coarser irregularities vanish and the contrast of details is mainly dependent on their albedo.

The photographs of the far side of the Moon transmitted in 1959 by LUNA-3 were obtained during a phase near the fullmoon. They allowed the establishment of an important peculiarity of the invisible hemisphere, namely the sharp prevalence of continental regions. The only new mare, revealed on the photographs, which by their reflecting properties and regular shape unquestionably deserves its name, is Mare Moscoviense, with average diameter not exceeding 300 km.

On photograph obtained from ZOND-3 there are no somewhat significant mare regions on the far side of the Moon, except for two, quite limited in area regions to the South of Mare Orientale, which incidently, was also obtained for the first time without distortions (see Fig.1) Two regions of maria, divided by a crest, and again detected, are extensions of bands of Mare Autumni and Mare Veris.

The photographs did not corroborate the existence of the hypothetical Mare Parvum; ($\beta = -51.1°$, $\lambda = -91.6°$), noted by Franz in the libration zone of the invisible hemisphere [1] and introduced into the Catalogue MAC No.2 257a [2].

In the region indicated there is, nevertheless, a certain darkening of "lake" type surface without clearly outlined boundary.

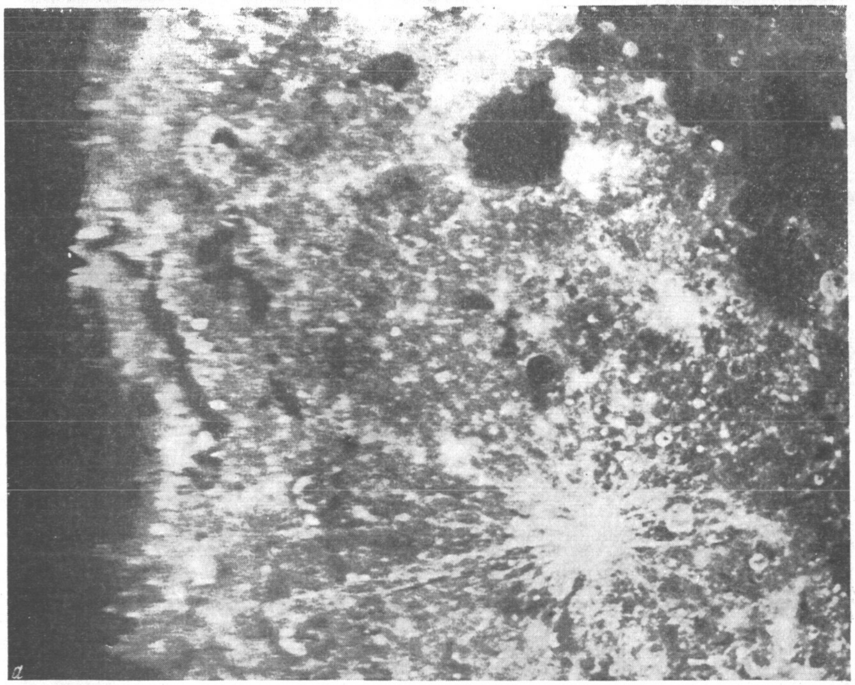
Nor are apparently confirmed the Franz considerations relative to the ocean of the far side of the Moon [4] (see the following section). The same ocean was indicated on the Wilkins a priori sketch-map of the far side of the Moon, which, except for some systems of rays intersecting the boundary of the visible hemisphere, has on the whole no real content.

Therefore, the photographs of the eastern sector of the far side of the Moon confirm the soundness of the previous conclusion already derived from the results of the study of the 1959 photographing material relative to the prevalence on the far side of the Moon of a continental landscape [6]. Nowadays it has been finally established that the northern and southern continental shields, disconnected on the visible hemisphere, are joined in a single continental block on the invisible side of the Moon. Consequently, when characterizing the nature of the lunar surface, it is appropriate to adhere to the conception of global continental mantle, while the dark mare and oceanic surfaces — the result of inundation as a consequence of partial depressions of lunar crust — ought to be considered only as closed intracontinental disseminations.

3. Of fundamental significance is the discovery on the invisible hemisphere of the Moon of specific depressions reaching hundreds of kilometers in diameter. The depressions with clear sempatic craters and mainly a continental-type bottom have in a sufficient degree a regular, oval shape and are comparable in areas with most of lunar maria. The study of the indicated depressions inescapably suggests that their genesis is in many respects similar to the maritime, though contrary to the latter, they escaped subsequent inundation and thereby did not receive the comparatively smooth dark-tone surface characterizing the maria. Because of the analogy with maria we introduced for the descri . l depressions the term "thalassoid"(mare-like).

We brought out in Fig.2 a sketch-map of a thalassoid with a diameter of 540 km; the coordinates of thalassoid's center are $\beta = 0°$, $\lambda = -131°$. Particularly clearly outlined on photographs is the thalassoid near the terminator with coordinates of the center $\beta = -7°$ $\lambda = -163°$ (Fig.3). Both thalassoids clearly show central oval ranges (plateforms) and a ring-shaped throw.

Therefore two-types of annular depressions are revealed on the lunar surface, which may be united by a single designation as basins. Such a subdivision was already contemplated during the study of the coarser details of the visible hemisphere. For example, Khabakov [7] called attention to the fact that Mare Nectaris occupies only a part of a broad depression between the Altai crest to the East and the Pyrenaeus to the West (Fig.4). The territory between these crests constitutes an oval trough 1100-1200 km in diameter, which is strewn with craters and continental-type irregularities and tone, that is, similar in the whole to thalassoid depressions. The central region of the thalassoid, flooded in latest geologic epochs, is designated nowadays as Mare Nectaris.



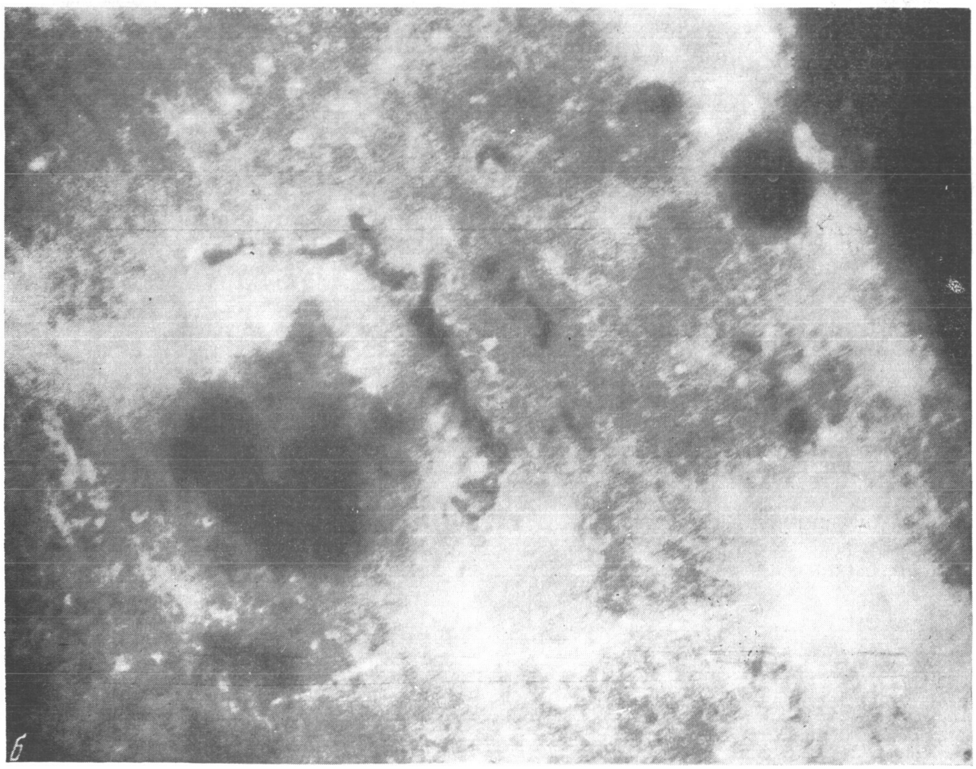


Fig.1. Continental region between Oceanus Procellarum and Mare Orientalis. The bright crater with a system of rays in the lower right-hand part of the photograph is Byrgius A:

a) according to the rectified photograph obtained from Earth [4];
b) same region according to one of the first photos of AIS Zond-3. Seen to the South of Mare Orientalis are two regions of maria, revealed again and constituting the extension of the loops of Mare Autumni and Mare Veris. According to this photograph it may be considered that Mare Orientalis is bordered by a closed ring of mountain ranges.

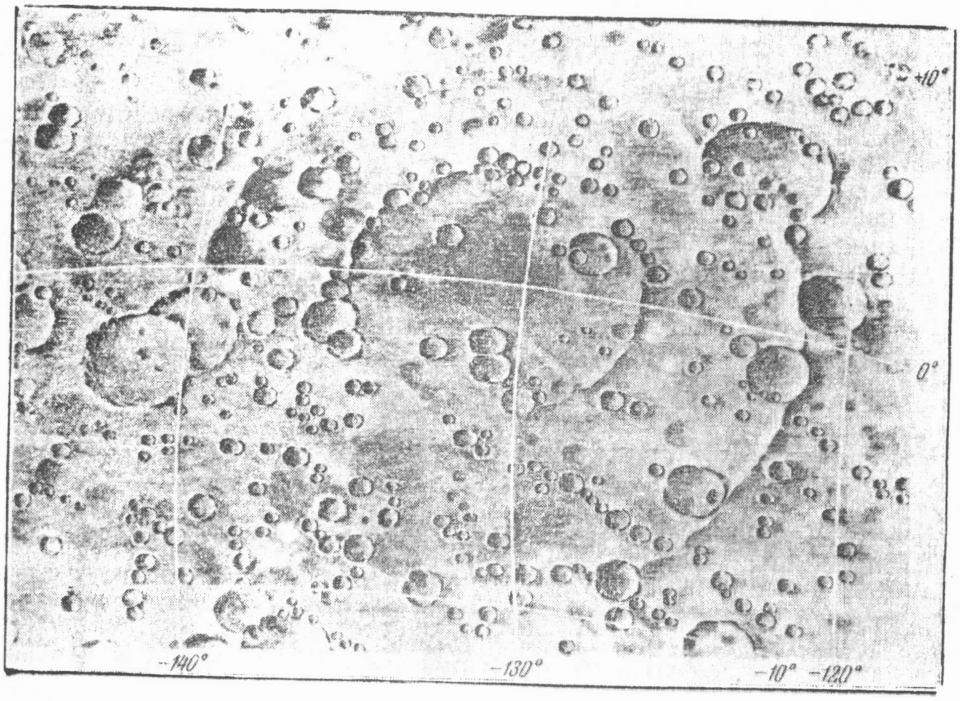


Fig.2. Sketch-map of a thalassoid
($\beta = 0°$, $\lambda = -131°$)
The illumination is northwesterly. The central platform and the two chains of craters crossing the thalassoid are reinforced. This sketch was prepared by Zh. F. Rodinova

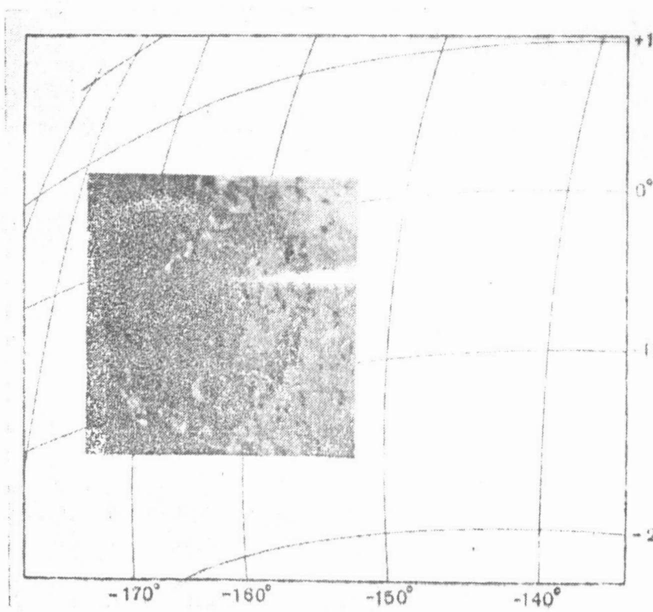


Fig.3. Thalassoid Korolev after photo of Zond-3
Very well outlined in this thalassoid of 390 km diameter and lying near the terminator is the internal platform and other details. This thalassoid was also identified on photographs of the far side of the Moon obtained in 1959 by Luna-3

The diameter of Mare Nectaris is of 400 km. Such a geological structure on the visible side of the Moon serves as a descriptive demonstration and example of transitional formation from an ancient thalassoid to a younger mare.

The question about lunar basins of the visible hemisphere has been the object of a detailed study with the application of the rectification method described in the work [8] by Hartmann and Kuiper. They have found the signs of 12 concentric basins on the visible side. There exists in the central parts of numerous basins a clearly outlined oval "platform" surrounded by small throws or folds. Thus, the well known crater Grimaldi constitutes a basin with an outward mountain range with a dark platform at the center. Note that one of the basins indicated by these authors near Schiller constitutes a typical small-size thalassoid (Fig.5). All the 12 outlined basins are surrounded from outside by annular mountain ranges.

Such a somewhat preconceived approach to outlining lunar basins leads, however, to the fact that none few typically regular maria, such as Mare Serenitatis, Mare Tranquillitatis, Mare Smythii and others, are found among them. In our opinion, the indispensable criterion of a basin is the regularity of the shape, while the accompanying annular mountain ranges do serve as a sufficient indication.

Besides the analogy close to thalassoids indicated by Hartmann and Kuiper it is possible to point at a well known region, designated since 1949 as Deslandres [9], which was often also designated in literature up until now as Hell Plain [10]. Wilkins and Moore [11] called it Hörbiger, after Faut. With its 250 km diameter Deslandres yields in dimensions to thalassoids of the far side; but there is, however, foundation to consider it, as well as other similar formations, as a link between thalassoids and the standard cirque or ring formations analogously to such crater maria as Grimaldi, Mare Australe and others being intermediate links between typical regular lunar maria and craters of average dimensions with dark bottom (Cruger, Billy, Plato).

The discovery of thalassoids provides the basis to turn again to the analysis of certain photographic material of 1959 concerning the far side of the Moon. It was then noted, in particular, that Mare Ingenii is somewhat more lucid than Mare Smithii and Mare Marginis having served as standards. This singularity was interpreted as a consequence of discrete structure of Mare Ingenii, assumingly consisting similarly to Mare Australe of a series of cirques and crater maria [12]. At present it is permissible to assume that either Mare Ingenii or part of it constitute thalassoids.

In this connection, the region lying in the borderline zone of new photographs at the latitude of Mare Ingenii, also offers interest. Although any conclusions in this regard are still premature, the possibility cannot be entirely excluded that Mare Ingenii is only part of the gigantic formation of the "oceanic" Thalassoid type, of which the center remained in a still not photographed narrow zone adjacent to the South Pole. Incidently, the Montes Leibnitz range, beyond which there begins, according to [8], still another lunar basin already on the far side, is located precisely in the region of the South pole.

As a result of the reprinting of photographs obtained from Luna-3, there emerged the possibility of making more precise the structure and the mutual disposition of numerous formations. In particular, it may be considered as established that Mare Moscoviense is surrounded by an intermittent ring of white spots.

4. The impact theory of lunar relief formation considers the mare as a result of sporadic collisions with planetesimals [13, 14]. However, attention has been drawn for quite a long time to the excpetionally important circumstance, contradicting the impact theory, that maria of the visible hemisphere are not chaotically distributed at all, but form a wide belt concentrical to a certain large circumference of the lunar sphere [4]. Basing himself upon this observed regularity, Franz had forecast the extension of belt of maria and the presence of a second ocean on the far side of the Moon, though in other prognoses, contradictory pronouncements were made by him.

The study of photographs from LUNA-3 has shown that no belt of maria exists on the far side of the Moon as a single complex of once flooded formations, of which a large part communicate among themselves by "narrows", though the position of Mare Ingenii, in unison with maria of eastern borderline zone of the visible hemisphere partially confirmed the trend revealed. After the 1959 photographing it appeared to be probable that maria form a chain, locally broken, with a widest central spread (overflow) in the region of Oceanus Procellarum.

Photographs of ZOND-3 leave still less room for the hypothesis, whereby there exists a second ocean on the far side of the Moon, and a certain, if only partially linked chain of maria from Oceanus Procellarum and Mare Orientale in the direction toward Mare Ingenii. Therefore, the Franz's belt of maria was found to be an unfounded extrapolation of the character of the visible hemisphere to the invisible, which in reality differ sharply from one another.

However, on the whole the oval lunar basins, such as are maria, the flooded depressions, as well as thasalloids, have an obvious tendency to be disposed in the form of a wide belt, of which the South pole coordinates are $\beta = -55°$ and $\lambda = -20°$. Franz considered that belt's South pole of the visible hemisphere has for coordinates: $\beta = -67°$, $\lambda = 0°$ [4].

The dashed line in Fig.6 indicates the boundaries, distant by $\pm 30°$ in latitude from the equator of the belt of global depressions. Beyond the zone outlined are found to exist only Mare Moscoviense, Mare Humboldtianum and the marginal maria adjacent to Oceanus Procellarum, which is obviously linked with the latter's particularities due to its large dimensions. Cataclysms, having attended the formation of Oceanus Procellarum being quite apparently insignificant in depth, encompassed at the same time enormous expanses.

The fact that oceanic and mare surfaces formed on account of either cause as a consequence of inundation of ancient, earlier crater-covered subsidings, is indisputable. It is corroborated by traces of semi-inundated craters in Oceanus Procellarum, within Mare Nectaris, Mare Humorum and many others.

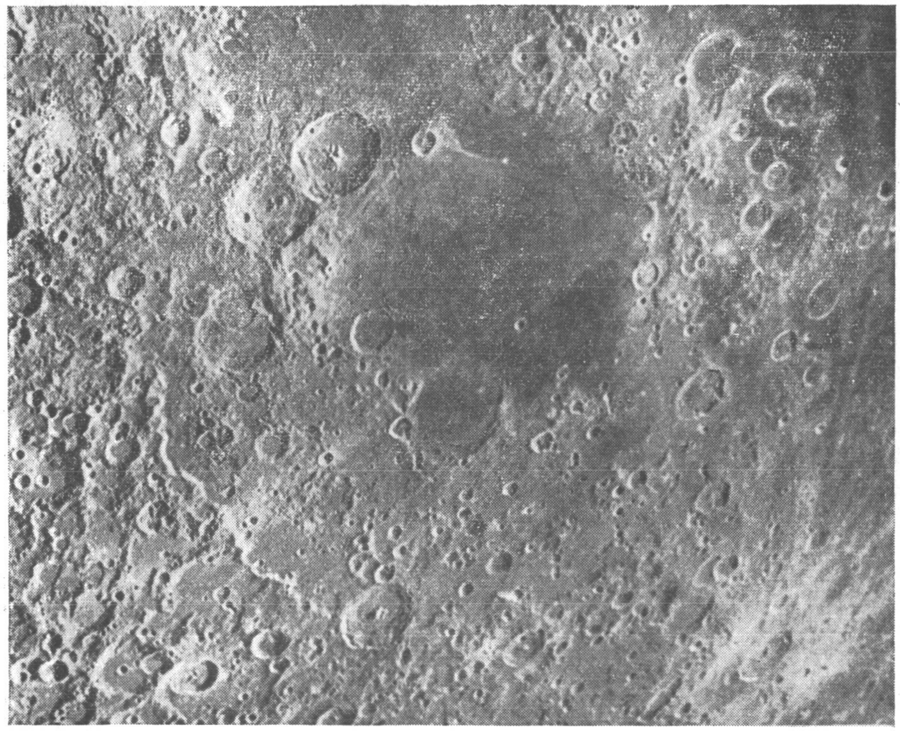


Fig.4. Region of Mare Nectaris

Altai Mountains to the East and Pyrenees to the West constitute boundaries of a broad depression, of which the flooded part is namely called Mare Nectaris. This region serves as an example of the transitional formation between the mare and the thalassoid

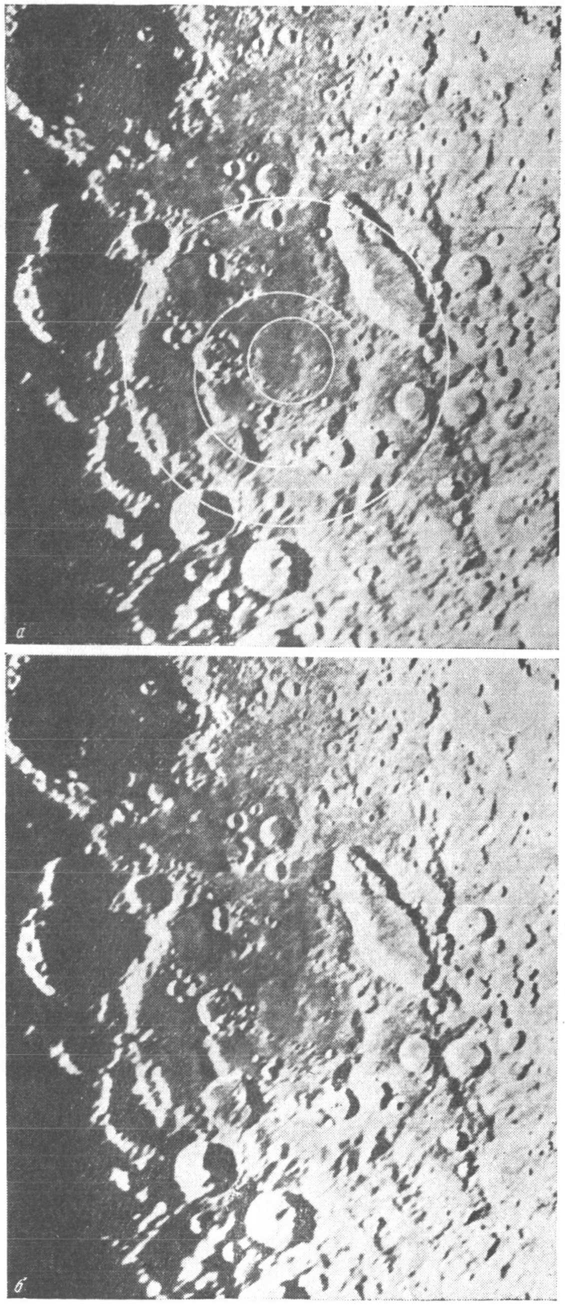


Fig.5. Lunar basin of 350 km in diameter near the Schiller crater

By its peculiarities this basin is the most typical thalassoid on the visible side of the Moon

Obviously, the inundation of irregularly-shaped maria and bays, adjacent to Oceanus Procellarum, such as Mare Vaporum, Mare Frigoris, Mare Nubium, Mare Cognitum, Sunus Medii, Sinus Aestuum, Sinus Roris, should be interpreted as being the result of wide superficial irruptions from the central part of Oceanus Procellarum.

As already pointed out, the dark inundated territories may be subdivided according to their natural characteristics into three categories. Referred to the first category are maria of regular oval shape; the belt of depressions is formed mostly by them. To the second category we may relate the small crater maria, and also the irregular valleys with maritime tone. All these "flocky shreds" or fragments of mare surface have a clearly expressed tendency in their distribution over the lunar surface: they are concentrated in the "seaside" regions of the lunar continent in the western and eastern borderline zones [15]. Finally, Oceanus Procellarum and maria of irregular shape should be referred to the third category; some of them may be recognized in essence as being "bays" of the Ocean. All the indicated maria are connected with Oceanus Procellarum and constitute quite obviously a single overflow. The tone of maria of this group are relatively lighter, with islands of quasicontinental structure encountered on their surface.

It is natural to consider that the formation of the ring of gigantic depressions took place in a single geologic epoch, but for one reason or another, the depressions of the visible side were inundated by a lava-like or analogous to it substance, while on the far side no such inundation took place. It is of fundamental importance to establish whether this difference is directly linked with the action by the Earth, or this connection is indirect while the phenomenon is casual.

As is well known, there is basis to assume that once the Moon rotated about its own axis much more rapidly than at present. In such a case the shape of the Moon was obviously determined by the combined actions of gravitation and centrifugal force. When under the effect of tidal deceleration of the centrifugal force the rotation velocity of the Moon notably decreased, the equilibrium shape took another form, wherefore emerged the chain of gigantic equatorial subsidings, having given way to the ring of valleys. The angle between the central plane of the valley ring and the contemporary equator, according this viewpoint, defines the previous inclination of Moon's equator to the ecliptic plane, which constitutes as in the case of the Earth and Mars, 20 to 30°.

The variety of shapes and of detail distribution on the Moon point to the significant inhomogeneity of the lunar crust. Such a nonuniformity in the distribution of crust material is observed on all planets of which the surfaces are accessible to observations. The asymmetry in the distribution of the major global details on Earth, Mars, Mercury and major satellites is a general trait of heavenly bodies. This is why the diversity in the character of distribution of separate details of the depression ring is quite natural. As to the prevalence of overflown depressions, that is, maria, on the side turned at the Earth, this may be a casual event.

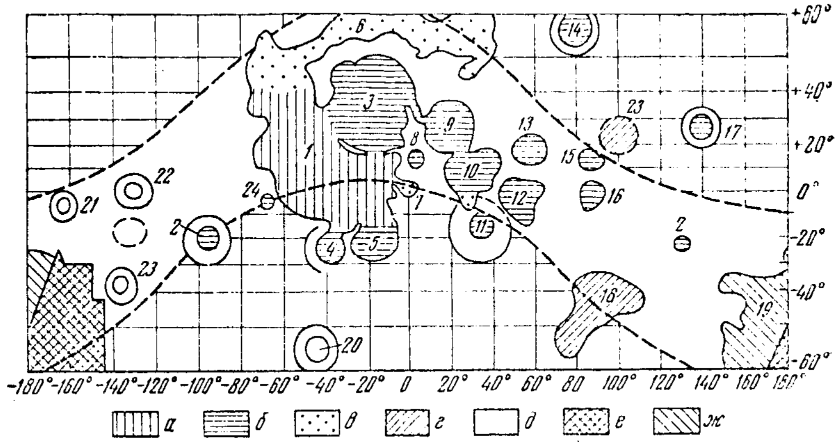


Fig.6. Global belt of depressions on the lunar surface.

Coordinates of the South pole of the global belt: $\beta = -55°$, $\lambda = -20°$. 1) Oceanus Procellarum, 2) Tsiolkovskiy crater mare, 3) Mare Imbrium, 4) Mare Humorum, 5) Mare Nubium, 6) Mare Frigoris, 7) Sinus Medii, 8) Mare Vaporum, 9) Mare Serenitatis, 10) Mare Tranquillitatis, 11) Mare Nectaris, 12) Mare Foecundidatis, 13) Mare Crisium, 14) Humboldtianum, 15) Mare Marginalis, 16) Mare Smythii, 17) Mare Moscoviense, 18) Mare Australe, 19) Mare Ingenii 20) Basin near Schiller, 21) Thalassoid Korolev, 22) and 23) Thalassoids of the far side of the Moon, 24) Grimaldi crater mare, 25) Dark region near the Joliot-Curie crater, a - Ocean, b - Maria of regular oval shape, c - Maria of irregular shape, d - mosaic (inlaid) maria, e - thalassoids, f - unphotographed part of the Moon, g - Mare Ingenii. Composed by Zh. F. Rodionova.

On the other hand, in the problem of depression inundating of the visible hemisphere one cannot entirely exclude the possibility of direct influence of the Earth during the last stage of deceleration of the axial rotation of the Moon in the process of which the conditions on the visible and invisible hemispheres of the Moon were unquestionably nonidentical. The energy liberated at Moon's deceleration was apparently sufficient for the development of endogenous processes topped off by the inundation of depressions of the hemisphere turned at the Earth; however, the mechanism of this possible phenomenon is still obscure in its details.

A general glimpse on the distribution of mare and continental surfaces reveals still one more peculiarity. The Korolev thalassoid ($\beta = -7°$, $\lambda = -163°$) has for antipode a mountainous-continental block to the North of Sinus

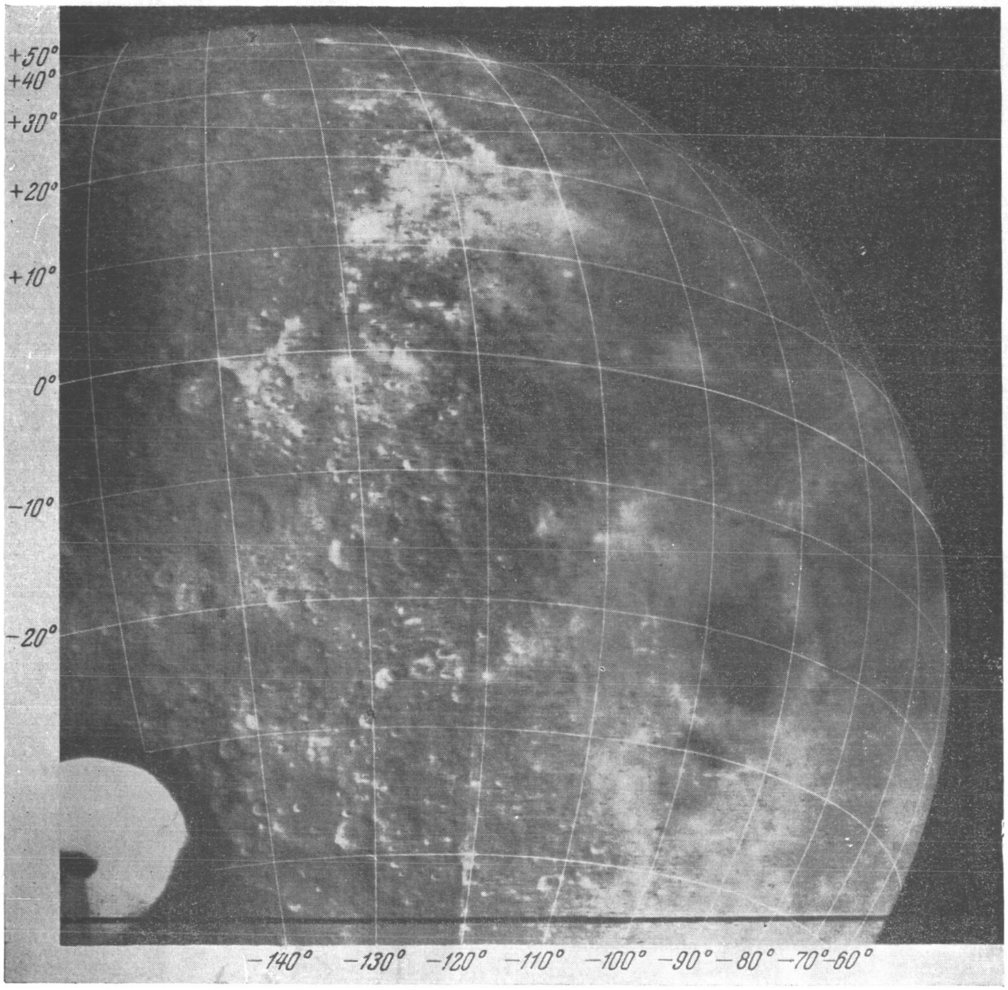


Fig.7. One of the published photographs of AIS "ZOND-3" with imprinted coordinate net

The precision of coordinate net plotting is ±0.5°

Medii rich in cracks. Obviously, the formation of both regions is related to the premare period. It is not clear whether such an antipodal situation is a consequence of lunar crust's perturbations during the emergence of the thalassoid, focused at the antipodal point, or it is the result of differential effect of attraction of the Sinus Medii region located in the middle of the visible hemisphere. There exist also antipodal basins. Thus Mare Humorum is antipodal relative to Mare Moscoviense, Mare Imbrium to Mare Ingenii, Mare Foecunditatis to the thassaloid of coordinates ($\beta = 0°$, $\lambda = --131°$), Mare Orientalis to Mare Marginalis. However, on the whole the question of antipodal formations of the lunar sphere requires further data accumulation with reference, in particular, to the peculiarities of the mesorelief of the regions studied.

5. The rows of craters and cirques, as widespread forms of lunar relief, are well known from observations of the visible hemisphere [16]. In its various regions numerous formations of similar kind are revealed; they are characteristic of the tracked down mutual relationship of the chain of craters, dosposed one after another. The dimensions of separate objects constituting the rows fluctuate within the broadest ranges: from craterlets of diameters of hundreds of meters and less, visible on the photographs of Ranger spacecrafts, and those of 1 - 5km in diameter [in the vicinity of Copernicus, Sirsalis or near the ancient cirque Vendelinus] to the gigantic cirques constituting the series or rows Ptolemaeus-Alphonsus- Arzachel-Thebit-Purbach-Regiomontanus Walter-Nonius-Fernelius-Stofler. As ... evident from Ranger photographs, the system of rays apparently is a parent form of relief t- crater chains. Some of crater chains observed on the visible side, are disposed along fissures and formations of fault type. The opinion is propounded that the direction of the rows and chains is closely correlated with the regional directions of the general system of fractures on the surface of the Moon [7, 17].

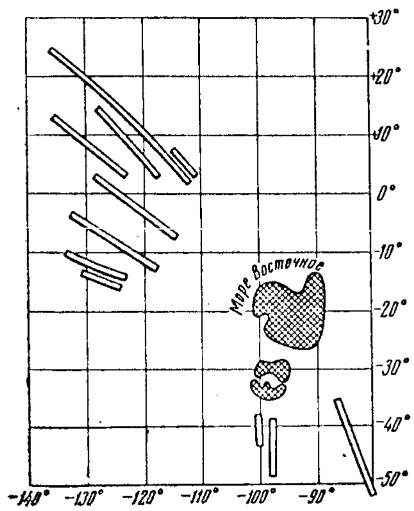


Fig.8. Plan-sketch of the chain of craters in the region of Mare Orientalis.

By their extension and the number of craters comprising them, the chains revealed on the photographs of ZOND-3 (see, for example, Fig. 7), to the northwest of Mare Orientalis, differ sharply from those known on the visible hemisphere; this allows us to speak in terms of exclusiveness of these formations. The length of the most extended chain attains 1100 km, and the number of craters with diameter from 20 to 40 km reaches to 40. The clearly expressed direction of the rediscovered crater rows converging toward to clear continental region to the North of Mare Orientalis (see Fig.8) is striking. Incidently, the greatest of the crater chains Sirsalis is also adjacent to that region [10]. The possibility is not excluded that the trend revealed may point to the presence of a system of tectonic fractures in this region of the lunar sphere also. From this viewpoint, the further detailed study and description of the indicated formations offers a substantial interest.

6. It should be recalled that the Moon occupies amongst the other satellites quite an individualized place. First of all, the Moon to Earth mass ratio is anomalously great, at least by one order exceeding its value for other satellites. Secondly, the Moon is located beyond the sphere where the attraction of the central planet prevails over that of the Sun, which provides certain scientists with a basis to consider the system Earth-Moon as a dual planet [18]. This was used also as a pretext to develop the viewpoint, whereby the Moon was found to be captured by the Earth during the later evolution stage, and the lunar dimension was typical of protoplanetary bodies in the entire Solar system [19]. By the same token, the determination of the spot occupied by the Moon amongst major planets and their satellites, appears to be quite important.

TABLE 1

CERTAIN PHYSICAL CHARACTERISTICS OF MAJOR PLANETS AND THEIR SATELLITES [21 - 23]

Object	Mass 10^{26} g	Visual Albedo λ 5500 Å	Equator. Radius, km	Gravit. accel. on equat.*	Solar const. cal/cm^{2}min	Escape velocity km/sec
Jupiter	18 990	0.67	71 825	2 300	0.0702	57.7
Saturn	5 680	0.69	60 335	910	0.0208	33.1
Neptune	1 030	0.84	22 300	1 350	0.0021	24.6
Uranus	870	0.93	23 550	970	0.0052	21.6
Pluto	?	0.14	?	?	0.0012	?
Earth	60	0.39	6 378	980	1.90	11.2
Venus	49	0.76	6 114	870	3.64	10.3
Mars	6.4	0.16	3 400	372	0.81	5.0
Mercury	3.3	0.056	2 420	380	12.7	4.3
Ganymed	1.6	0.34	2 800	[illegible]	0.0702	2.9
Triton	1.4	0.32	2 000	245	0.0021	3.1
Titan	1.4	0.24	2 480	176	0.0208	2.8
Callisto	1.0	0.15	2 520	130	0.0702	2.4
Moon	0.7	0.067	1 740	162	1.90	2.4
Io	0.7	0.54	1 780	182	0.0702	2.5
Europa	0.5	0.73	1 550	151	0.0702	2.1

* in cm/sec^2

As is well known, the subdivision of planets into two groups has a specific significance: the terrestrial and the Jupiter group. Otherwise planets are classified by their transparency characteristic of their atmospheres [20]. In such a case planets-giants and Venus are considered as planets with optically dense atmospheres, the observation of surfaces of which is still impossible. Opposed to them are planets and satellites with optically thin atmospheres, or totally devoid of them (Earth, Mars, Titan, Mercury, Moon, Ganymede, Callisto, etc.).

The last subdivision basically coincides with the classification by the degree of atmosphere density (physical), which is best justified from the standpoint of the accounting for the influence upon the surface of factors of atmospheric and cosmic origin.

The results of experiments on MARINER-4 have made apparent quite an unexpected for most of the researchers analogy between Mars and the Moon. The investigated surface of Mars was found to be dug up by craters, fundamentally analogous to lunar craters, and also by large basins or troughs, suggesting lunar maria and thalassoids. As communicated, no indications of "canals" on the surface of Mars were revealed.

The analogy between Mars and the Moon is hardly casual. In either case the basic relief-forming factors are endogenous and cosmic influences, while the role of water and eolian erosion is either reduced to a minimum or altogether absent. This remains valid also for all celestial bodies with rarefied atmospheres. The above considerations allow us to reach the conclusion that the Moon, whose surface is of easiest access for observations and is now being studied most intensively, is a typical representative of a large group of planets and satellites devoid of dense atmospheres. Evidently, this conclusion cannot be extended indefinitely; for the well known influence on relief formation is also exerted by such specific factors, as the axial rotation, the drifting away from the Sun and so forth.

We compiled in Table 1 certain physical characteristics for the representatives of both above-analyzed groups of planets and satellites; the jump of the charcteristics between these two groups is evident.

The practical consequences of the fact of existence of a clear physical group Mars-Moon are invaluable. In connection with this new possibilities open up for diversified comparisons, for the analysis of conditions on planets and satellites as a result of the study of the nearest and already accessible for experimental research, celestial body -- the Moon. It may be said that the completion of a global review of lunar surface and the photographing of Mars from close distance opens up a new epoch in the investigation of objects of this type.

The authors avail themselves of the opportunity to express their thanks for the help in this work by the co-workers of the Division of Physics of the Moon and Planets of the State Astronomical Institute in the name of Shternberg, L. I. Bondarenko, Zh. F. Rodionova and V. V. Novikov.

*** THE END ***

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